WHAT IS CLAIMED IS:

1. A device for calculating diffraction efficiencies of a diffraction lens divided into a plurality of regions, each region comprising at least one grating ring, the device comprising:

a first memory for storing information about diffraction efficiencies of said regions;

a second memory for storing information about weights corresponding to said regions; and

a first processor for retrieving information from said first and said second memories, and calculating diffraction efficiencies of the entire diffraction lens using the formula

(1) $$E_j = \sum_{m=1}^{M} W_m \eta_{mj}$$

wherein:

j : integer indicating the order of diffraction light

$E_j$ : diffraction efficiency for j–th order diffraction light of the diffraction lens

M : positive integer (M > 1) indicating the number of regions for which the diffraction efficiency is calculated

m : index of the region for which the diffraction efficiency is calculated

$\eta_{mj}$ : diffraction efficiency for the j–th order diffraction light of the m–th region (stored in the first memory)

$W_m$ : weight for the m–th region (stored in the second memory means).

2. The device according to Claim 1, further comprising:

a third memory for storing information about a relief cross–section shape of the diffraction lens;

a fourth memory for storing information about a wavelength of a light source;

a fifth memory for storing information about a refractive index of a material of the diffraction lens at said wavelength;

a second processor for retrieving information from said third, fourth

and fifth memories, and calculating diffraction efficiencies of said regions of the diffraction lens; and

a first repeating means for operating said second processor for a number of times that is equal to the number of said regions;

wherein the diffraction efficiencies $\eta_{mj}$ stored in said first memory are calculated using said third, fourth and fifth memories, said second processor, and said first repeating means.

3. The device according to Claim 1, wherein each grating ring of the diffraction lens corresponds to one of said regions.

4. The device according to Claim 2, wherein said second processor performs a calculation using a Fourier transformation.

5. The device according to Claim 1, further comprising a calculating means for calculating the weights stored in said second memory using information about the diffraction lens.

6. The device according to Claim 1, further comprising:

a sixth memory for storing information about surface areas of said regions of the diffraction lens, and

a third processor for retrieving information from said sixth memory, and calculating weights using the formula

(2) $$W_m = \frac{S_m}{\sum_{i=1}^{M} S_i}$$

wherein:

$S_m$ : surface area of the m–th region

$W_m$ : weight of the m–th region

M : number of regions into which the lens is divided

m : index counting the regions into which the lens is divided

i : integer ,

wherein the weights corresponding to the regions stored in said second memory are calculated using said sixth memory and said third

processor.

7. The device according to Claim 1, further comprising:

a seventh memory for storing information about radii of the grating rings of the diffraction lens; and

a third processor for retrieving information from said seventh memory, and calculating weights using the formulas

(3) $$W_1 = \frac{R_1^{\ 2}}{R_M^{\ 2}}$$ and

(4) $$W_m = \frac{R_m^{\ 2} - R_{m-1}^{\ 2}}{R_M^{\ 2}} \quad (m > 1)$$

wherein:

$R_m$ : m–th grating ring radius counted from the center of the lens

$W_m$ : weight of the m–th grating ring

M : number of grating rings

m : index counting the grating rings from the center of the lens

wherein the weights corresponding to the regions stored in said second memory are calculated using said seventh memory and said third processor.

8. The device according to Claim 1, further comprising:

a seventh memory for storing information about radii of the grating rings of the diffraction lens;

an eighth memory for storing information about an intensity distribution for a light beam that is incident on the diffraction lens; and

a third processor for retrieving information from said seventh and eighth memories and calculating the weights so that they are substantially proportional to the light intensity of the light that is incident on the corresponding grating ring of the diffraction lens;

wherein the weights corresponding to the regions stored in said second memory are calculated using said seventh and eighth memories and said third processor.

9. The device according to Claim 2, further comprising a calculating means for calculating the cross–section shape of the diffraction lens stored in the third memory.

10. The device according to Claim 2, further comprising:

a ninth memory for storing information about a relief profile design for the diffraction lens;

a tenth memory for storing information about a processing bit that is used for cutting the diffraction lens or cutting a die for forming the diffraction lens;

a fourth processor for retrieving information from said ninth and tenth memories, and calculating a relief profile of a diffraction lens that was cut with the processing bit or a relief profile of a diffraction lens formed using a die that was cut with the processing bit; and

a second repeating means for repeatedly operating said fourth processor;

wherein the cross–section shape of the diffraction lens stored in said third memory is calculated using said ninth and said tenth memories, said fourth processor, and said second repeating means.

11. The device according to Claim 2, further comprising:

a ninth memory for storing information about a relief profile design for the diffraction lens;

a tenth memory for storing information about a processing bit that is used for cutting the diffraction lens or cutting a die for forming the diffraction lens;

an eleventh memory for storing information about feed speed of said processing bit;

a fourth processor for retrieving information from said ninth, tenth, and eleventh memories, and calculating a relief profile of a diffraction lens that was cut with the processing bit or a relief profile of a diffraction lens formed using a die that was cut with the processing bit; and

a second repeating means for repeatedly operating said fourth processor;

wherein the cross–section shape of the diffraction lens stored in said third memory is calculated using said ninth, tenth and eleventh

memories, said fourth processor, and said second repeating means.

12. A device for calculating diffraction efficiencies of a diffraction lens divided into a plurality of regions, each region comprising at least one grating ring, the diffraction efficiencies corresponding to a plurality of wavelengths, and the device comprising:

a first memory for storing information about diffraction efficiencies of said regions at the plurality of wavelengths;

a second memory for storing information about weights corresponding to said regions;

a third memory for storing information about a relief cross–section shape of the diffraction lens;

a fourth memory for storing information about the plurality of wavelengths;

a fifth memory for storing information about refractive indices of a material of the diffraction lens at said wavelengths;

a fourth processor for calculating a relief cross–section shape of the diffraction lens stored in said third memory;

a second processor for retrieving information from said third, fourth and fifth memories, and calculating therefrom diffraction efficiencies of said regions at said plurality of wavelengths stored in said first memory;

a third repeating means for operating said second processor for a number of times that is equal to the number of said wavelengths;

a fourth repeating means for operating said third repeating means for a number of times that is equal to the number of said regions; and

a first processor for retrieving information from said first and said second memory, and calculating diffraction efficiencies of the entire diffraction lens using the formula

(5) $$E_{jl} = \sum_{m=1}^{M} W_m \eta_{mjl}$$

wherein:

j : integer indicating the order of diffraction light

l : index of the wavelengths

$E_{jl}$ : diffraction efficiency for j–th order diffraction light of the diffraction lens at the l–th wavelength

M : positive integer ($M > 1$) indicating the number of regions for which the diffraction efficiency is calculated

m : index of the region for which the diffraction efficiency is calculated

$W_m$ : weight for the m–th region

$\eta_{mjl}$ : diffraction efficiency for the j–th order diffraction light of the m–th region at the l–th wavelength

13. A lens–shape measurement apparatus for measuring the surface shape of a measurement object selected from the group consisting of a diffraction lens and a die for a diffraction lens, the apparatus comprising:

a shape measuring means for measuring the surface shape of said measurement object;

a processor device for substantially eliminating at least one of the macroscopic components selected from the group consisting of a spherical surface, an aspherical surface, and a plane from measurement data obtained with said shape measuring means; and

a device for calculating diffraction efficiencies of the diffraction lens based on the measured data from which said macroscopic component has been substantially eliminated;

wherein said device for calculating diffraction efficiencies is a device according to one of the claims 1 to 8.

14. The lens–shape measurement apparatus according to Claim 13, further comprising:

a decision means for deciding whether said measurement object is a die or a lens; and

a data reversal means for reversing said measurement data if said measurement object is a die.

15. An apparatus for designing diffraction lenses, comprising:

an input for entering lens design data; and

a processor for calculating optical properties and diffraction efficiencies of the diffraction lens obtained on the basis of said design data;

wherein the processor for calculating the diffraction efficiencies is a device for calculating diffraction efficiencies according to one of the Claims 9 to 12.

16. The apparatus according to Claim 15, wherein said design data comprises initial data and correction data, for correcting initial data.

17. A diffraction lens designed using the apparatus according to Claim 15.

18. A method for calculating diffraction efficiencies of a diffraction lens divided into a plurality of regions, each region comprising at least one grating ring, the method comprising:

a first memory step of storing information about diffraction efficiencies of said regions;

a second memory step of storing information about weights corresponding to said regions; and

a first processing step of retrieving information stored in said first and said second memory step, and calculating diffraction efficiencies of the entire diffraction lens using the formula

(1) $$E_j = \sum_{m=1}^{M} W_m \eta_{mj}$$

wherein:

j : integer indicating the order of diffraction light

$E_j$ : diffraction efficiency for j–th order diffraction light of the diffraction lens

M : positive integer (M > 1) indicating the number of regions for which the diffraction efficiency is calculated

m : index of the region for which the diffraction efficiency is calculated

$\eta_{mj}$ : diffraction efficiency for the j–th order diffraction light of the m–th region (stored in the first memory step)

$W_m$ : weight for the m–th region (stored in the second memory step).

19. The method according to Claim 18, further comprising:

a third memory step of storing information about a relief cross–section shape of the diffraction lens;

a fourth memory step of storing information about a wavelength of a light source;

a fifth memory step of storing information about a refractive index of a material of the diffraction lens at said wavelength;

a second processing step of retrieving information stored in said third, fourth and fifth memory step, and calculating diffraction efficiencies of said regions of the diffraction lens;

a first repeating step of repeating said second processing step for a number of times that is equal to the number of said regions;

wherein the diffraction efficiencies $\eta_{mj}$ stored in said first memory step are calculated using said third, fourth and fifth memory step, said second processing step, and said first repeating step.

20. The method according to Claim 18, wherein each grating ring of the diffraction lens corresponds to one of said regions.

21. The method according to Claim 19, wherein said second processing step includes a calculation using a Fourier transformation.

22. The method according to Claim 18, further comprising a calculating step of calculating the weights stored in said second memory step using information about the diffraction lens.

23. The method according to Claim 18, further comprising:

a sixth memory step of storing information about surface areas of said regions of the diffraction lens, and

a third processing step of retrieving information stored in said sixth memory step, and calculating weights using the formula

(2) $$W_m = \frac{S_m}{\sum_{i=1}^{M} S_i}$$

wherein:

$S_m$ : surface area of the m–th region

$W_m$ : weight of the m–th region

M : number of regions into which the lens is divided

m : index counting the regions into which the lens is divided
i : integer ,

wherein the weights corresponding to the regions stored in said second memory step are calculated using said sixth memory step and said third processing step.

24. The method according to Claim 18, further comprising:

a seventh memory step for storing information about radii of the grating rings of the diffraction lens; and

a third processing step for retrieving information stored in said seventh memory step, and calculating weights using the formulas

(3) $$W_1 = \frac{R_1^{\ 2}}{R_M^{\ 2}}$$ and

(4) $$W_m = \frac{R_m^{\ 2} - R_{m-1}^{\ 2}}{R_M^{\ 2}} \quad (m > 1)$$

wherein:
$R_m$ : m–th grating ring radius counted from the center of the lens
$W_m$ : weight of the m–th grating ring
M : number of grating rings
m : index counting the grating rings from the center of the lens

wherein the weights corresponding to the regions stored in said second memory step are calculated using said seventh memory step and said third processing step.

25. The method according to Claim 18, further comprising:

a seventh memory step of storing information about radii of the grating rings of the diffraction lens;

an eighth memory step of storing information about an intensity distribution for a light beam that is incident on the diffraction lens; and

a third processing step of retrieving information stored in said

seventh and eighth memory step and calculating the weights so that they are substantially proportional to the light intensity of the light that is incident on the corresponding grating ring of the diffraction lens;

wherein the weights corresponding to the regions stored in said second memory step are calculated using said seventh and eighth memory step and said third processing step.

26. The method according to Claim 19, further comprising a calculating step of calculating the cross–section shape of the diffraction lens stored in the third memory step.

27. The method according to Claim 19, further comprising:

a ninth memory step of storing information about a relief profile design for the diffraction lens;

a tenth memory step of storing information about a processing bit that is used for cutting the diffraction lens or cutting a die for forming the diffraction lens;

a fourth processing step of retrieving information stored in said ninth and tenth memory step, and calculating a relief profile of a diffraction lens that was cut with the processing bit or a relief profile of a diffraction lens formed using a die that was cut with the processing bit; and

a second repeating step of repeating said fourth processing step;

wherein the cross–section shape of the diffraction lens stored in said third memory step is calculated using said ninth and said tenth memory step, said fourth processing step, and said second repeating step.

28. The method according to Claim 19, further comprising:

a ninth memory step of storing information about a relief profile design for the diffraction lens;

a tenth memory step of storing information about a processing bit that is used for cutting the diffraction lens or cutting a die for forming the diffraction lens;

an eleventh memory step of storing information about feed speed of said processing bit;

a fourth processing step of retrieving information stored in said ninth, tenth, and eleventh memory step, and calculating a relief profile of a diffraction lens that was cut with the processing bit or a relief profile of a

diffraction lens formed using a die that was cut with the processing bit; and

a second repeating step of repeating said fourth processing step;

wherein the cross–section shape of the diffraction lens stored in said third memory step is calculated using said ninth, tenth and eleventh memory step, said fourth processing step, and said second repeating step.

29. A method for calculating diffraction efficiencies of a diffraction lens divided into a plurality of regions, each region comprising at least one grating ring, the diffraction efficiencies corresponding to a plurality of wavelengths, and the method comprising:

a first memory step of storing information about diffraction efficiencies of said regions at the plurality of wavelengths;

a second memory step of storing information about weights corresponding to said regions;

a third memory step of storing information about a relief cross–section shape of the diffraction lens;

a fourth memory step of storing information about the plurality of wavelengths;

a fifth memory step of storing information about refractive indices of a material of the diffraction lens at said wavelengths;

a fourth processing step of calculating a relief cross–section shape of the diffraction lens stored in said third memory step;

a second processing step of retrieving information stored in said third, fourth and fifth memory step, and calculating therefrom diffraction efficiencies of said regions at said plurality of wavelengths stored in said first memory step;

a third repeating step of repeating said second processing step for a number of times that is equal to the number of said wavelengths;

a fourth repeating step of repeating said third repeating step for a number of times that is equal to the number of said regions; and

a first processing step of retrieving information stored in said first and said second memory step, and calculating diffraction efficiencies of the entire diffraction lens using the formula

(5) $$E_{jl} = \sum_{m=1}^{M} W_m \eta_{mjl}$$

wherein:

$j$ : integer indicating the order of diffraction light

$l$ : index of the wavelengths

$E_{jl}$ : diffraction efficiency for j–th order diffraction light of the diffraction lens at the l–th wavelength

$M$ : positive integer ($M > 1$) indicating the number of regions for which the diffraction efficiency is calculated

$m$ : index of the region for which the diffraction efficiency is calculated

$W_m$ : weight for the m–th region

$\eta_{mjl}$ : diffraction efficiency for the j–th order diffraction light of the m–th region at the l–th wavelength .

30. A method for calculating diffraction efficiencies of a diffraction lens by measuring the surface shape of a measurement object selected from the group consisting of a diffraction lens and a die for a diffraction lens, the method comprising:

a shape measuring step of measuring the surface shape of said measurement object;

a processing step of substantially eliminating at least one of the macroscopic components selected from the group consisting of a spherical surface, an aspherical surface, and a plane from measurement data obtained in said shape measuring step; and

a step of calculating diffraction efficiencies of the diffraction lens based on the measured data from which said macroscopic component has been substantially eliminated;

wherein said step of calculating diffraction efficiencies is a method according to one of the claims 18 to 25.

31. The method for calculating diffraction efficiencies according to Claim 30, further comprising:

a decision step of deciding whether said measurement object is a die or a lens; and

a data reversal step of reversing said measurement data if said measurement object is a die.

32. A method for designing diffraction lenses, comprising:

an input step of entering lens design data;

a processing step of calculating optical properties and diffraction efficiencies of the diffraction lens obtained on the basis of said design data;

an optimization step of optimizing the lens properties based on the result of the processing step;

wherein the processing step of calculating the diffraction efficiencies is a method for calculating diffraction efficiencies according to one of the Claims 26 to 29.

33. The method according to Claim 32, wherein said optimizing step optimizes aberration and diffraction efficiency.

34. A diffraction lens designed using the method according to Claim 32.

35. A computer–readable recording medium storing a computer–executable program for calculating diffraction efficiencies of a diffraction lens divided into a plurality of regions, each region comprising at least one grating ring, wherein the program executes:

a first memory step of storing information about diffraction efficiencies of said regions;

a second memory step of storing information about weights corresponding to said regions; and

a first processing step of retrieving information stored in said first and said second memory step, and calculating diffraction efficiencies of the entire diffraction lens using the formula

(1) $$E_j = \sum_{m=1}^{M} W_m \eta_{mj}$$

wherein:

j : integer indicating the order of diffraction light

$E_j$ : diffraction efficiency for j–th order diffraction light of the diffraction lens

M : positive integer ($M > 1$) indicating the number of regions for which the diffraction efficiency is calculated

m : index of the region for which the diffraction efficiency is calculated

$\eta_{mj}$ : diffraction efficiency for the j–th order diffraction light of the m–th region (stored in the first memory step)

$W_m$ : weight for the m–th region (stored in the second memory step).

36. The recording medium according to Claim 35, wherein the program further executes:

a third memory step of storing information about a relief cross–section shape of the diffraction lens;

a fourth memory step of storing information about a wavelength of a light source;

a fifth memory step of storing information about a refractive index of a material of the diffraction lens at said wavelength;

a second processing step of retrieving information stored in said third, fourth and fifth memory step, and calculating diffraction efficiencies of said regions of the diffraction lens; and

a first repeating step of repeating said second processing step for a number of times that is equal to the number of said regions;

wherein the diffraction efficiencies $\eta_{mj}$ stored in said first memory step are calculated using said third, fourth and fifth memory step, said second processing step, and said first repeating step.

37. The recording medium according to Claim 35, wherein each grating ring of the diffraction lens corresponds to one of said regions.

38. The recording medium according to Claim 36, wherein said second processing step includes a calculation using a Fourier transformation.

39. The recording medium according to Claim 35, wherein the program further executes a calculating step of calculating the weights stored in said second memory step using information about the diffraction lens.

40. The recording medium according to Claim 35, wherein the program further executes:

a sixth memory step of storing information about surface areas of said regions of the diffraction lens, and

a third processing step of retrieving information stored in said sixth

memory step, and calculating weights using the formula

(2) $$W_m = \frac{S_m}{\sum_{i=1}^{M} S_i}$$

wherein:

$S_m$ : surface area of the m–th region
$W_m$ : weight of the m–th region
M : number of regions into which the lens is divided
m : index counting the regions into which the lens is divided
i : integer

wherein the weights corresponding to the regions stored in said second memory step are calculated using said sixth memory step and said third processing step.

41. The recording medium according to Claim 35, wherein the program further executes:

a seventh memory step for storing information about radii of the grating rings of the diffraction lens; and

a third processing step for retrieving information stored in said seventh memory step, and calculating weights using the formulas

(3) $$W_1 = \frac{R_1^{\,2}}{R_M^{\,2}}$$ and

(4) $$W_m = \frac{R_m^{\,2} - R_{m-1}^{\,2}}{R_M^{\,2}} \quad (m > 1)$$

wherein:

$R_m$ : m–th grating ring radius counted from the center of the lens
$W_m$ : weight of the m–th grating ring
M : number of grating rings
m : index counting the grating rings from the center of the lens

wherein the weights corresponding to the regions stored in said second memory step are calculated using said seventh memory step and said third processing step.

42. The recording medium according to Claim 35, wherein the program further executes:

a seventh memory step of storing information about radii of the grating rings of the diffraction lens;

an eighth memory step of storing information about an intensity distribution for a light beam that is incident on the diffraction lens; and

a third processing step of retrieving information stored in said seventh and eighth memory step and calculating the weights so that they are substantially proportional to the light intensity of the light that is incident on the corresponding grating ring of the diffraction lens;

wherein the weights corresponding to the regions stored in said second memory step are calculated using said seventh and eighth memory step and said third processing step.

43. The recording medium according to Claim 36, wherein the program further executes a calculating step of calculating the cross–section shape of the diffraction lens stored in the third memory step.

44. The recording medium according to Claim 36, wherein the program further executes:

a ninth memory step of storing information about a relief profile design for the diffraction lens;

a tenth memory step of storing information about a processing bit that is used for cutting the diffraction lens or cutting a die for forming the diffraction lens;

a fourth processing step of retrieving information stored in said ninth and tenth memory step, and calculating a relief profile of a diffraction lens that was cut with the processing bit or a relief profile of a diffraction lens formed using a die that was cut with the processing bit; and

a second repeating step of repeating said fourth processing step;

wherein the cross–section shape of the diffraction lens stored in said third memory step is calculated using said ninth and said tenth memory

step, said fourth processing step, and said second repeating step.

45. The recording medium according to Claim 36, wherein the program further executes:

a ninth memory step of storing information about a relief profile design for the diffraction lens;

a tenth memory step of storing information about a processing bit that is used for cutting the diffraction lens or cutting a die for forming the diffraction lens;

an eleventh memory step of storing information about feed speed of said processing bit;

a fourth processing step of retrieving information stored in said ninth, tenth, and eleventh memory step, and calculating a relief profile of a diffraction lens that was cut with the processing bit or a relief profile of a diffraction lens formed using a die that was cut with the processing bit; and

a second repeating step of repeating said fourth processing step;

wherein the cross–section shape of the diffraction lens stored in said third memory step is calculated using said ninth, tenth and eleventh memory step, said fourth processing step, and said second repeating step.

46. A computer–readable recording medium storing a computer–executable program for calculating diffraction efficiencies of a diffraction lens divided into a plurality of regions, each region comprising at least one grating ring, the diffraction efficiencies corresponding to a plurality of wavelengths, wherein the program executes:

a first memory step of storing information about diffraction efficiencies of said regions at the plurality of wavelengths;

a second memory step of storing information about weights corresponding to said regions;

a third memory step of storing information about a relief cross–section shape of the diffraction lens;

a fourth memory step of storing information about the plurality of wavelengths;

a fifth memory step of storing information about refractive indices of a material of the diffraction lens at said wavelengths;

a fourth processing step of calculating a relief cross–section shape of the diffraction lens stored in said third memory step;

a second processing step of retrieving information stored in said third, fourth and fifth memory step, and calculating therefrom diffraction efficiencies of said regions at said plurality of wavelengths stored in said first memory step;

a third repeating step of repeating said second processing step for a number of times that is equal to the number of said wavelengths;

a fourth repeating step of repeating said third repeating step for a number of times that is equal to the number of said regions; and

a first processing step of retrieving information stored in said first and said second memory step, and calculating diffraction efficiencies of the entire diffraction lens using the formula

(5) $$E_{jl} = \sum_{m=1}^{M} W_m \eta_{mjl}$$

wherein:

$j$ : integer indicating the order of diffraction light

$l$ : index of the wavelengths

$E_{jl}$ : diffraction efficiency for j–th order diffraction light of the diffraction lens at the l–th wavelength

$M$ : positive integer ($M > 1$) indicating the number of regions for which the diffraction efficiency is calculated

$m$ : index of the region for which the diffraction efficiency is calculated

$W_m$ : weight for the m–th region

$\eta_{mjl}$ : diffraction efficiency for the j–th order diffraction light of the m–th region at the l–th wavelength .

47. A computer–readable recording medium storing a computer–executable program for calculating diffraction efficiencies of a diffraction lens by measuring the surface shape of a measurement object selected from the group consisting of a diffraction lens and a die for a diffraction lens, wherein the program executes:

a shape measuring step of measuring the surface shape of said measurement object;

a processing step of substantially eliminating at least one of the macroscopic components selected from the group consisting of a spherical

surface, an aspherical surface, and a plane from measurement data obtained in said shape measuring step; and

a step of calculating diffraction efficiencies of the diffraction lens based on the measured data from which said macroscopic component has been substantially eliminated;

wherein the program for executing said step of calculating diffraction efficiencies is a program stored in a recording medium according to one of the claims 35 to 42.

48. The recording medium according to Claim 47, wherein the program further executes:

a decision step of deciding whether said measurement object is a die or a lens; and

a data reversal step of reversing said measurement data if said measurement object is a die.

49. A computer–readable recording medium storing a computer–executable program for designing a diffraction lens, executing on a computer an evaluation function for evaluating lens properties; wherein said program contains a program stored on a recording medium according to one of the Claims 43 to 46.

50. A combined refraction / diffraction lens, comprising

a refraction lens; and

a diffraction lens comprising a plurality of concentric grating rings formed on at least one surface of the refraction lens;

satisfying the formula

(6) $$k = f\left(\frac{1}{f_g} + \frac{\nu_g}{f_d \nu_d}\right) \quad ,$$

wherein:

f : total focal length of said combined refraction / diffraction lens

$f_d$ : focal length of the diffraction lens

$f_g$ : focal length of the refraction lens

$\nu_d$ : partial dispersion coefficient at an applied wavelength region of the diffraction lens
$\nu_g$ : partial dispersion coefficient at an applied wavelength region of the refraction lens

wherein k satisfies $0.1 \leqq k$.

51. The combined refraction / diffraction lens according to Claim 50, wherein said k satisfies

$$0.2 \leqq k \leqq 0.8 .$$

52. A combined refraction / diffraction objective lens for use in an optical information recording / reproducing device, comprising:

a single lens having an ingoing surface and an outgoing surface; and

a diffraction lens comprising a plurality of concentric grating rings formed on at least one surface of the single lens;

satisfying the formula

$$k = f\left(\frac{1}{f_g} + \frac{\nu_g}{f_d \nu_d}\right) \quad (6)$$ ,

wherein:
f : total focal length of said combined refraction / diffraction objective lens
$f_d$ : focal length of the diffraction lens
$f_g$ : focal length of the refraction lens
$\nu_d$ : partial dispersion coefficient at an applied wavelength region of the diffraction lens
$\nu_g$ : partial dispersion coefficient at an applied wavelength region of the refraction lens

wherein k satisfies $0.2 \leqq k \leqq 0.6$.

53. The combined refraction / diffraction objective lens according to Claim 52, wherein said k satisfies

$$0.3 \leqq k \leqq 0.55 .$$

54. An optical head comprising

a light source;

a beam splitting means for splitting a light beam emitted from said light source;

a focussing means for focussing a light beam emitted from said light source on an information recording medium;

a photo–detector element for detecting a light beam that is reflected or a transmitted by said information recording medium,

wherein said focussing means comprises an objective lens according to Claim 52 or Claim 53.

55. A combined refraction / diffraction imaging lens comprising:

a single lens having an ingoing surface and an outgoing surface; and

a diffraction lens comprising a plurality of concentric grating rings formed on at least one surface of the single lens;

satisfying the formula

$$k = f\left(\frac{1}{f_g} + \frac{\nu_g}{f_d \nu_d}\right) \quad (6)$$

wherein:

f : total focal length of said combined refraction / diffraction imaging lens

$f_d$ : focal length of the diffraction lens

$f_g$ : focal length of the refraction lens

$\nu_d$ : partial dispersion coefficient at an applied wavelength region of the diffraction lens

$\nu_g$ : partial dispersion coefficient at an applied wavelength region of the refraction lens

wherein k satisfies $0.3 \leqq k$ .

56. The combined refraction / diffraction imaging lens according to Claim 55, wherein said k satisfies

$0.4 \leqq k \leqq 0.7$ .

57. An image pickup device comprising an imaging lens according to Claim 55 or Claim 56, an imaging element, and a signal processing circuit.

58. A lens with grating element wherein chromatic aberration is corrected by forming concentric relief rings on a surface of the lens to provide diffractive effect, the pitch $P_m$ of the relief rings satisfying the formula

(7) $$P_m > \sqrt{\frac{\lambda_1 \cdot f_d}{2m}} ,$$

where m is the ring number counted from the center of the lens, $f_d$ is the focal length of the grating element, and $\lambda_1$ is the principal wavelength of the grating element.

59. A lens with grating element wherein chromatic aberration is corrected by forming concentric relief rings on a surface of the lens to provide diffractive effect, said relief rings having pitches that gradually decrease to a certain position away from the optical axis, and gradually increase further away from said position.

60. A lens with grating element in which chromatic aberration is corrected by forming concentric relief rings on a surface of the lens to provide diffractive effect, satisfying the formula

(8) $$0.2 < \left|\frac{d}{r}\right| < 0.7 ,$$

where r is the effective radius of the grating element surface, and d is the distance of the innermost ring of the relief from the optical axis.

61. The lens with grating element according to any of claims 58 to 60, wherein the surface of said grating element has a kinoform profile.

62. The lens with grating element according to any of claims 58 to 60, wherein said lens with grating element is made of a material selected from the group consisting of glass and plastics.

63. The lens with grating element according to any of claims 58 to 60, wherein said lens with grating element is formed from an infrared absorbing material.

64. An imaging apparatus comprising at least the lens with grating element according to any of claims 58 to 60, an image pickup device, and a signal processing circuit.

65. A reading apparatus comprising at least the lens with grating element according to any of claims 58 to 60, an image sensor, and a signal processing circuit.

66. An optical system for reading optical information selected from the group consisting of image information and code information, comprising a lens wherein a grating element surface is formed on at least one surface of the lens.

67. The optical system for reading according to claim 66, which is capable of being moved on the optical axis by a driving device.

68. The optical system for reading according to claim 66 or 67, wherein the lens which constitutes the optical system for reading is only a single lens on which said grating element surface is formed, the image side surface of said lens is convex and has positive refractive power, and a diaphragm is placed at the object side from said lens.

69. The optical system for reading according to claim 68, which satisfies the formulas

(9) $0.05 < | r_2 / r_1 | < 0.5$ ,

(10) $9 < f / D < 16$ ,

and

(11) $0.05 < | f / f_d | < 0.15$ ,

where $r_1$ is the radius of curvature at the vertex of the object side surface of

said lens, $r_2$ is the radius of curvature at the vertex of the image side surface of said lens, D is the diameter of the diaphragm, f is the focal length of the entire optical system, and $f_d$ is the focal length of the grating element surface of said lens.

70. The optical system for reading according to claim 69, wherein at least one surface of said lens is an aspheric surface with a local radius of curvature that becomes smaller with increasing distance from the optical axis.

71. The optical system for reading according to claim 66 or 67, which satisfies the formula

(12) $450\ \text{nm} < \lambda_1 < 600\ \text{nm}$ ,

where $\lambda_1$ is the principal wavelength when the grating element surface is formed.

72. The optical system for reading according to claim 71, wherein the grating element surface has a kinoform profile.

73. The optical system for reading according to claim 66 or 67, wherein the lens having the grating element surface is made of a material selected from the group consisting of glass and plastics.

74. The optical system for reading according to claim 66 or 67, wherein the lens having the grating element surface is formed from an infrared absorbing material.

75. The optical system for reading according to claim 66 or 67, which satisfies the formula

(13) $0.2 < y / Y < 0.6$ ,

where Y is the maximum height of a manuscript, and y is the maximum height of an image sensor.

76. The optical system for reading according to claim 75, wherein the

meridional image surface has a better imaging performance than the sagittal image surface.

77. The optical system for reading according to claim 67, which satisfies the formula

(14) $$0.6 < Y_t / Y_w < 1 ,$$

where $Y_w$ is the maximum height of a manuscript when the optical system is moved closest to the object side, and $Y_t$ is the maximum height of a manuscript when the optical system is moved closest to the image side.

78. An image reading apparatus comprising

the optical system for reading according to claim 66 or 67,

an image sensor for converting image information that is imaged by said optical system for reading into electric signals, and

a circuit portion for processing said electric signals to process said image information.

79. A bar code reader comprising

the optical system for reading according to claim 66 or 67,

an image sensor for converting bar code information that is imaged by said optical system for reading into electric signals, and

a signal processing circuit having a circuit portion for decoding said bar code information.